Shotgun session

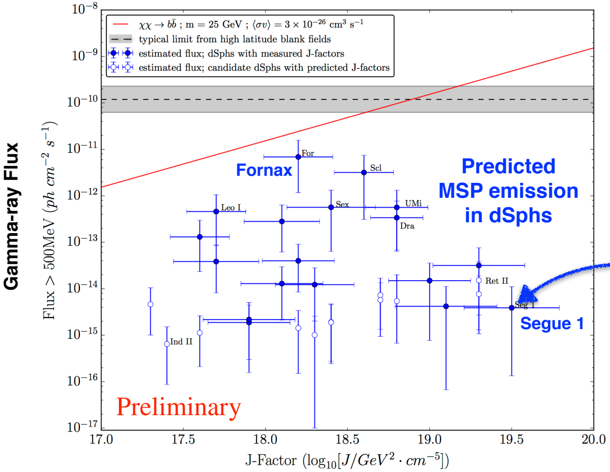
Our gun has 6 bullets:

- Thomas Andrews
- Keith Bechtold (double bullet)
- Yuuki Omori
- Mathew Madhavacheril
- Felipe Maldonado
- Paul Stankus

Thomas Andrews

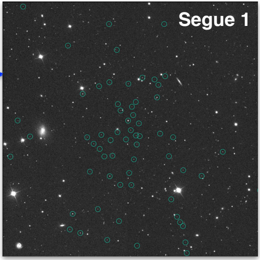
Estimating the GeV Emission of Millisecond Pulsars in Dwarf Spheroidal Galaxies

Keith Bechtol
WIPAC / Wisconsin-Madison



Dark matter annihilating at thermal relic cross section

Current *Fermi*-LAT sensitivity



Dark matter annihilation normalization factor for different astrophysical targets

Prospects for Associating TeV to PeV Cosmic Neutrinos with Explosive Optical Transients

Keith Bechtol
WIPAC / Wisconsin-Madison

Event coincidence rate with core-collapse SN

Fraction of total neutrino signal coming from CC SNe	x	Fraction of cumulative neutrino emission from optically detectable CC SNe	x	Purity of astrophysical neutrino event selection	=	**Coincidence rate per neutrino**
~1 (this is our hypothesis)		**~0.15** (complete to z ~ 0.15)		**~0.5** (achieved with appropriate event selection)		**~0.07**

False positive rate

Rate of similar optical transient events	x	Angular resolution of neutrino events	x	Temporal resolution of intrinsic neutrino emission AND optical transient timing	=	**Background rate per neutrino**
~0.003 deg^{-2} day^{-1} (will measure with LSST; assumes we can get redshift estimate for SN host)		**~0.16 deg^{2}** (IceCube track events)		**~10 day** (if neutrino emission is ~instantaneous, limited by optical light curve sampling and optical variability timescale)		**~0.005**

SPT x DES cross-correlations: SV results

Yuuki Omori (McGill) in collaboration with T. Giannantonio (Cambridge) & P. Fosalba (IEEC-CSIC), D. Kirk (UCL), Kyle Story (Stanford), Gil Holder (McGill) and many others+ in SPT and DES

McGill

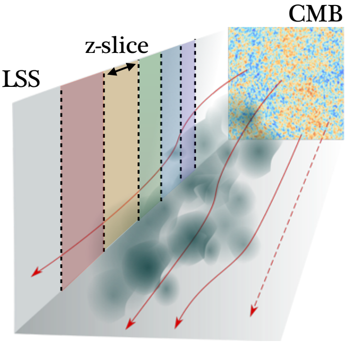
DARK ENERGY SURVEY

SOUTH POLE TELESCOPE

Galaxy clustering ⟷ CMB weak lensing

Galaxy weak lensing

?



Galaxy clustering x CMB WL arXiv: 1507.05551
Galaxy WL x CMB WL arXiv: 1512.04535

Measurement of a Cosmographic Distance Ratio with Galaxy and CMB Lensing

H. Miyatake, **Mathew Madhavacheril**, N. Sehgal, A. Slosar, D. Spergel, B. Sherwin, A. van Engelen

Based on arXiv:1605.05337

Stony Brook University, NY 11794

Introduction

Light from background sources is lensed by massive dark matter halos. The magnitude of the lensing effect depends on the distances to the lens and the source. By comparing the lensing signal from the same set of dark matter halos for two different sources, one can extract a purely geometric distance ratio that strongly constrains cosmological parameters that affect the expansion history, such as the dark energy equation of state w and curvature Ω_k, without being affected by systematics or modeling of the lensing matter distribution. [1, 2, 3] We present the first measurement that uses the longest possible lever arm for a distance ratio measurement by utilizing the cosmic microwave background (CMB) as one of the sources.

Data and Methodology

We use the CMASS sample of spectroscopic galaxies as lenses, known to reside in massive $\sim 10^{13}\ h^{-1}M_\odot$ halos at redshifts $0.4 < z < 0.7$. For the first source plane, the shapes of CFHTLens galaxies behind these lenses are used to obtain a tangential shear profile at an effective source redshift of around $z = 1.1$. We then use the *Planck* reconstruction of the CMB lensing convergence, cross-correlate it with the CMASS galaxy distribution and convert it through a Hankel transform

$$\langle \gamma_t^c(R) \rangle = \frac{1}{2\pi} \int \ell d\ell J_2(\ell R/\chi) C_\ell^{\kappa\delta_g}. \quad (1)$$

to the equivalent of tangential shear measured for the CFHTLens galaxies. We show the resulting shear profiles in the left panel of Figure 1.

Results

Since the lenses are the same, the projected density $\Delta\Sigma$ in $\gamma = \Delta\Sigma/\Sigma_{\rm cr}$ cancels in the ratio

$$r = \frac{\gamma_t^o}{\gamma_t^c} = \frac{\Sigma_{\rm cr}^{\rm CMB}}{\Sigma_{\rm cr}^{\rm opt}} = \frac{d_A(z^c) d_A(z^L, z^g)}{d_A(z^g) d_A(z^L, z^c)} \quad (2)$$

where the last equality holds for delta-function distributions of sources and lenses, and is the purely geometric quantity we wish to obtain. We forward model the full lens and source distributions and divide the lens sample into three thin redshift slices $0.43 < z < 0.51, 0.51 < z < 0.57$ and $0.57 < z < 0.7$. The resulting ratio is shown in the right panel of Figure 1.

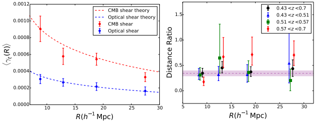


Figure 1: Left: CMB and optical shear around CMASS halos in the redshift range $0.43 < z < 0.7$. The dashed blue curve shows a theory fit to the optical data, which includes both the 1-halo and 2-halo terms. Right: The ratio of optical tangential shear and CMB shear as a function of distance from the center of CMASS lenses for various redshift slices of the lens sample.

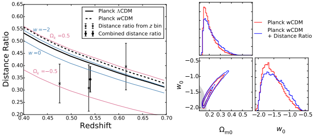


Figure 2: Left: Comparison of the measured distance ratio with that predicted from different cosmological models. Right: Constraints on Ω_{m0} and w_0. In the w_0 versus Ω_{m0} panel, the white and shaded regions show less than and more than 68% CL respectively from the distance ratio alone. The red curves show the 68% and 95% CL from the *Planck* TT + lowP spectra, and the blue curves show constraints from the combination of this distance ratio plus *Planck* TT + lowP.

We simultaneously fit the distance ratio to the three redshift slices. In doing this, we assume the ratio linearly depends on redshift, i.e., $r(z) = r_0 \quad r'(z - z_{\rm p})$, where $z_{\rm p}$ is the "pivot" redshift determined so that the errors on r_0 and r' are uncorrelated. This yields $r = 0.344 \pm 0.052$ at a pivot redshift of $z_{\rm p} = 0.54$, a 15% measurement of the distance ratio. To constrain cosmological parameters, we minimize the following quantity,

$$\chi^2(\Omega_{m0}, w_0) = \sum_\alpha \sum_{ij} d_i {\rm Cov}_{ij}^{-1} d_j, \quad (3)$$

where $d_i = \gamma^o(R_i) - r\gamma^c(R_i)$ for the ith radial bin and the index α runs over the three redshift slices. Cosmological constraints varying Ω_{m0} and w_0 are shown in the right panel of Fig 2. Future measurements using data from experiments like Advanced ACT, CMB Stage IV LSST and DESI are expected to yield <1% measurements of this ratio.

References

[1] B. Jain and A. Taylor. Cross-Correlation Tomography: Measuring Dark Energy Evolution with Weak Lensing. *Physical Review Letters*, 91(14):141302, October 2003.

[2] W. Hu, D. E. Holz, and C. Vale. CMB cluster lensing: Cosmography with the longest lever arm. *Phys. Rev. D*, 76(12):127301, December 2007.

[3] S. Das and D. N. Spergel. Measuring distance ratios with CMB-galaxy lensing cross-correlations. *Phys. Rev. D*, 79(4):043509, February 2009.

Signal-to-Noise ratio of Cross-Correlations between Future Surveys and CMB lensing

Felipe Maldonado

Florida State University

May 24, 2016

Mapping neutral hydrogen at mid red shifts via 21cm radio; demonstrator dish design and construction

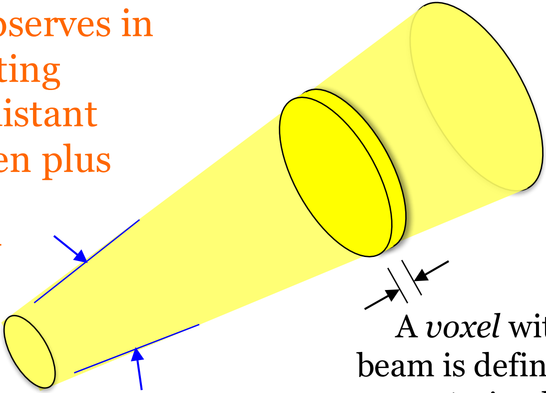
Paul Stankus

ORNL

Cross-Correlation Spectacular Poster, 24 May 2016

21cm voxels and the single dish

A single dish observes in a **beam**, collecting photons from distant neutral hydrogen plus "foregrounds", ratio S/N ~ 10^{-4}

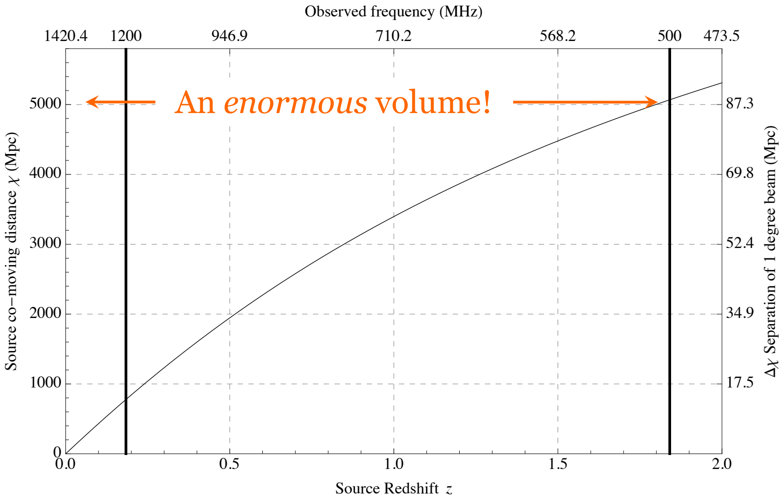


A *voxel* within the beam is defined via a range $\Delta\upsilon$ in observed frequency -> red shift -> radial distance

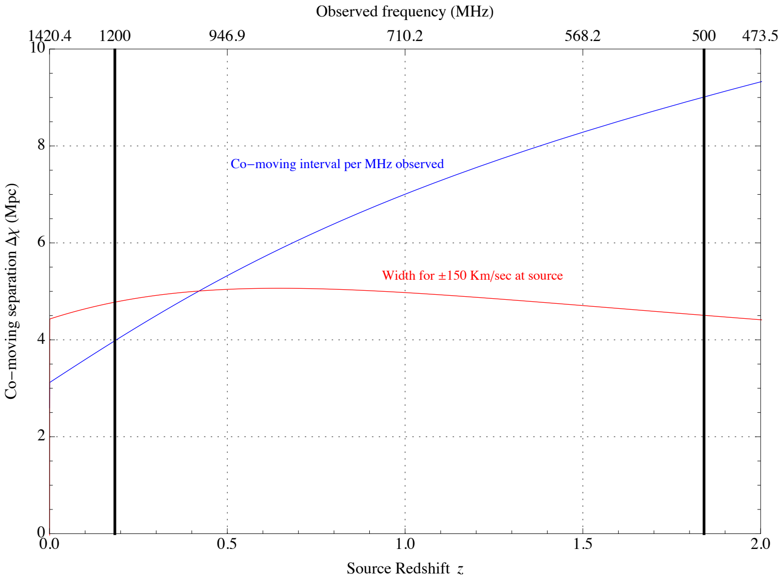
The angular width of the beam depends on the wavelength λ and dish aperture D as

$$\Delta\theta \sim \lambda/D$$

Co-moving distance *vs* red shift



Frequency -> spatial intervals



Basic dish/receiver specs

Mapping out densities across co-moving space, one natural/relevant scale for cosmology is the BAO scale, ~ 150 Mpc. The BAO feature itself is ~30 Mpc wide, so want to get to a resolution in co-moving coordinates of at least ~10 MPc, all the way back to z~2.

In frequency space, need to analyze power into individual frequency bins size $\Delta\upsilon$ ~1 MHz over a band ~400-1200 MHz; easy enough, with GHz digitizers.

Angular resolution is harder; eventually want ~30-100m dish diameter; will start with ~4m for demonstrator.

First-pass design for a light, home-brew off-axis 4m dish

Paul Stankus

ORNL

4 Feb 2016

Starting points

Goals:

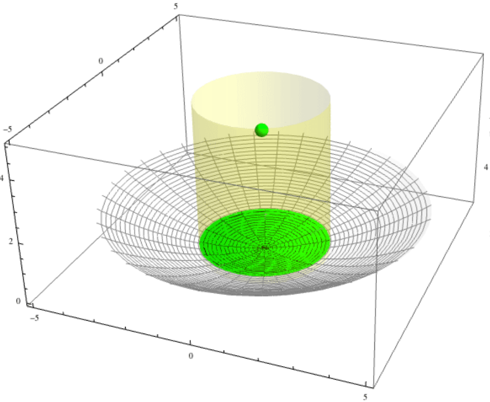
Inexpensive
Lightweight
Corrosion resistant
Uniform thermal expansion
Easy to machine & assemble
 -> all-Aluminum

Specs:

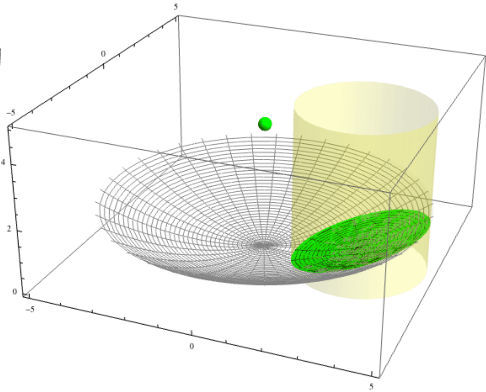
Aperture 4m at f/1.0
Reasonably round beam
Off-axis, clearance ~1m
Path-length tolerance ~1cm

Scientific tourism
Arecibo, April 2012

Paraboloids for beginners

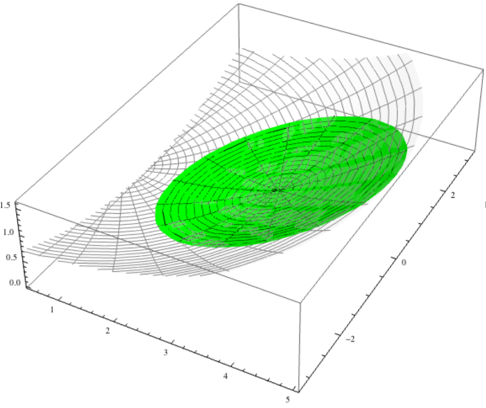


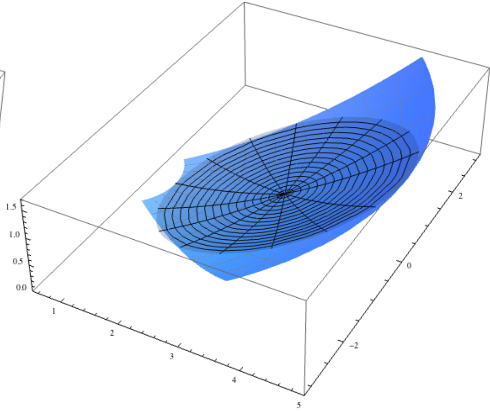
On-Axis: highly symmetric dish partially blocked by focus detector and supports



Off-Axis: less symmetric dish; will assume for now that beam direction is vertical

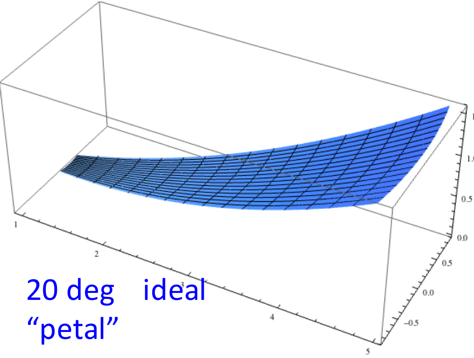
Friendly symmetry



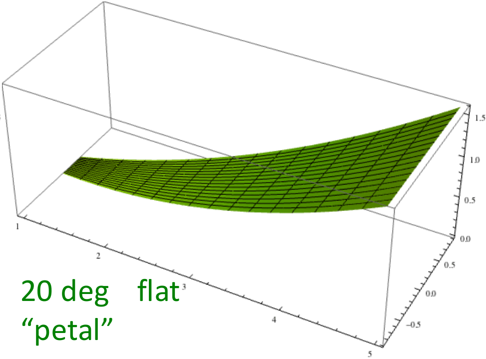


Can cover area of 4m diameter, 1m off-axis beam with a rotationally symmetric segment, R = 1—5m and about 80 degrees in azimuth; allows for repeated "flower petal" approach to construction.

The “flat petal” approximation



20 deg ideal
“petal”

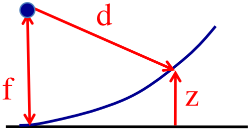


20 deg flat
“petal”

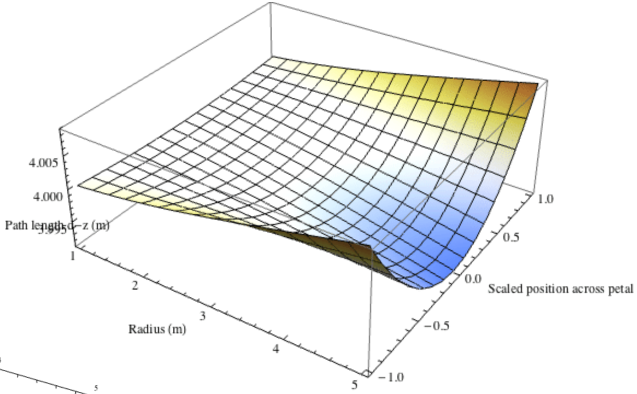
We want to **unroll** the reflector material with curvature in only one direction, **not hammer** it into a bowl with curvature in two directions.

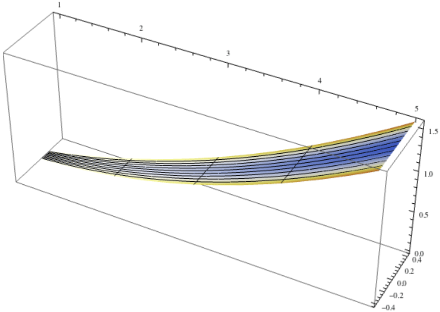
Q: How large a petal, in angle, can we tolerate at this radius?

Path length figure of merit



For a perfect paraboloid, d-z = f is constant over the surface





We can measure d-z over our flat petal, and see that for a 10-degree width the path length defect is everywhere less than +/- 1cm.

Two reflector rules of thumb:

1486 IEEE TRANSACTIO

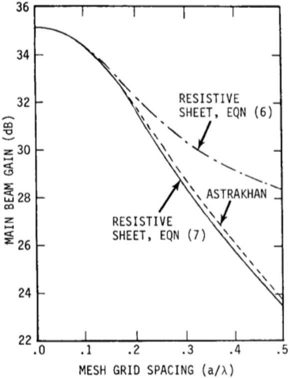
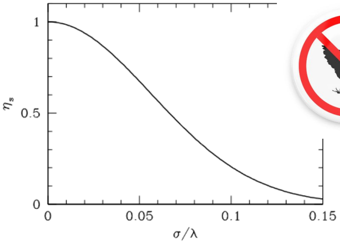


Fig. 3. Gain of a 20λ paraboloid as a function of mesh grid size. (f/D = 0.4, cos θ feed, r_0 = 0.002 λ.)

$$\eta_s = \exp\left[-\left(\frac{4\pi\sigma}{\lambda}\right)^2\right]$$

This is often called the ***Ruze equation***.



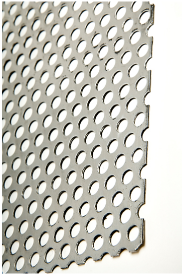
Grid spacing < 0.1 λ

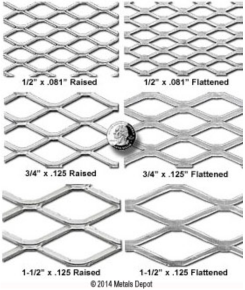
Flatness variation < 0.05 λ

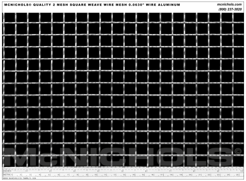
IEEE Trans. Ant. Prop. vol37 No11 1989

www.cv.nrao.edu/course/astr534/2DApertures.html

What can we unroll or flex a bit?



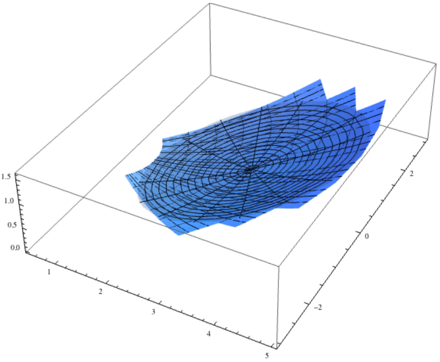


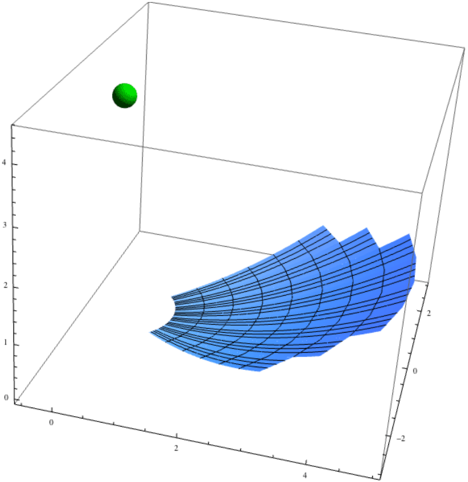


Perforated Al sheet 3/64"~1mm thick	Expanded Al sheet 0.081" thick	Al wire mesh 0.063" strand	Hardware cloth (galv. steel 0.25")
$50/m²	$45/m²	$25/m²	$9/m²
0.40 lb/ft²	0.45 lb/ft²	0.18 lb/ft²	0.16 lb/ft²
Added structural strength; best ground shield; solar concentrator (!)	Some structural strength, inexact attachments	Little structural strength, hard to keep flat	Very cheap; may be hard to keep flat; differing thermal expansion

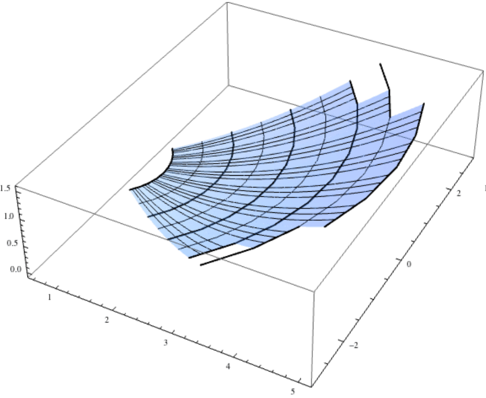
Full flat-petal coverage

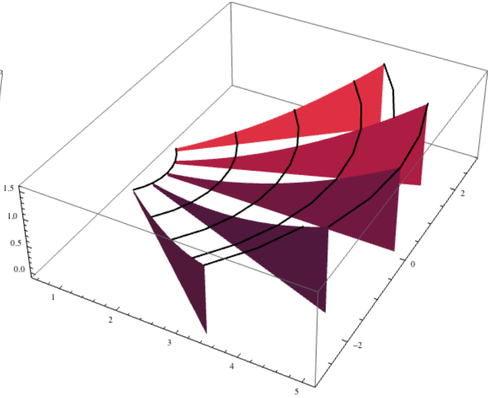
We can cover the nominal round beam quite nicely using eight 10-degree flat petals at 3.0m, 3.5m and 4.0m lengths





Structural support 1: cross bars

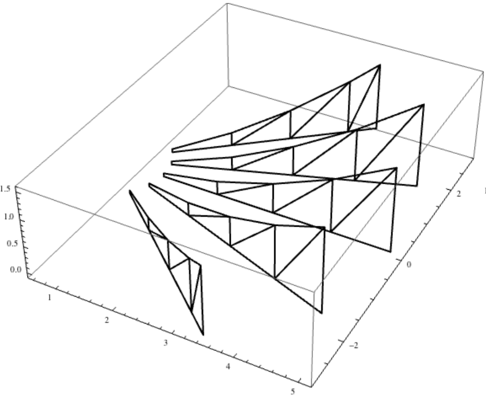




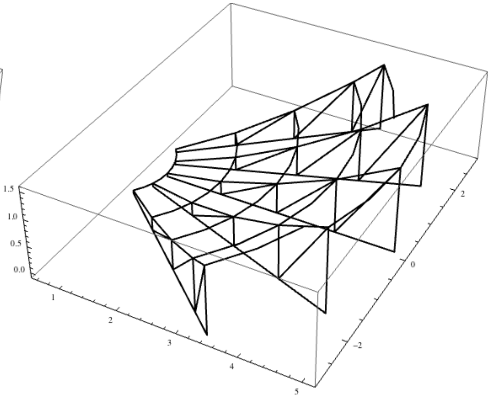
The gently curving flat petals are supported on cross-bars, here spaced every ~1m; presumably fine-tuned with screw stems for final alignment.

The cross-bars can be supported in any number of ways; effectively a truss web shown here, spaced one per two 10-degree petals.

Structural support 2: trusses

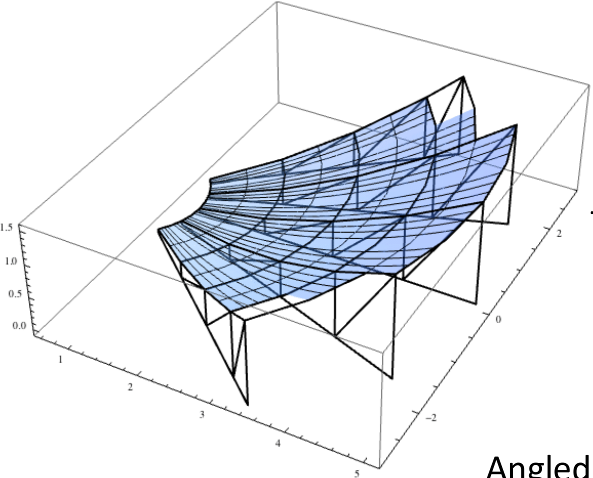


The lightest solution for supporting an extended length will always be a truss of some kind; many options are possible; truss planes are vertical if beam axis is vertical.



Full frame for the flat petals, with crossbars supported by trusses. (Additional box crosses not shown.)

Nominal parts lists

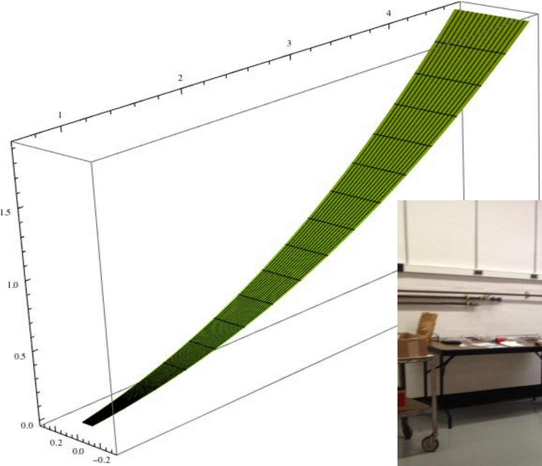


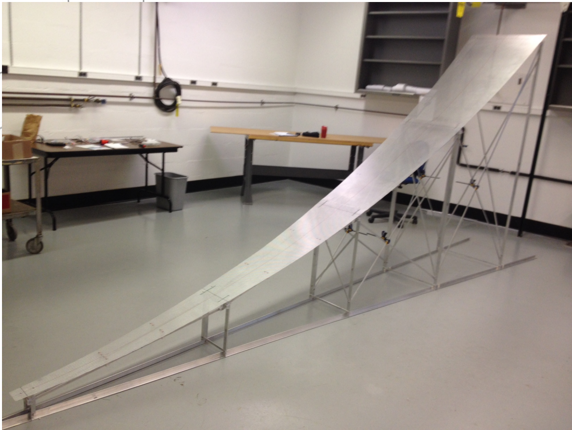
Petal area ~ 14 m^2
Weight 70 – 190 lb
Parts cost $150 – $700

Truss and crossbars
Total length ~ 350 ft
Al bar 1/8” x 3/4”
Weight ~35-50+ lb
Parts cost $200 – $300

Angled joints at crossbars
3-D printed precision non-flat wedge washers, ~x100 (free?)

From math to metal





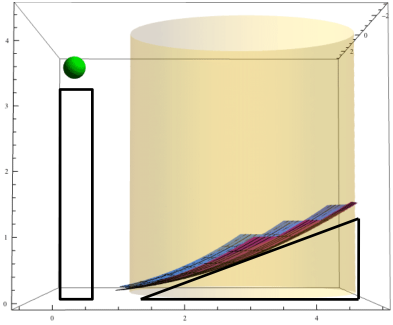
Ask for a tour!

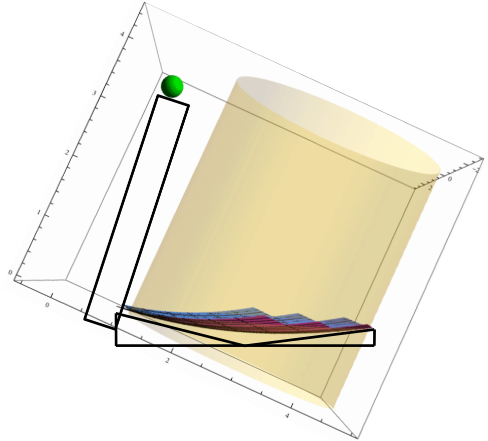
Summary thoughts

- It should be possible to build a very light (100-200 lb) dish satisfying: 4m diameter, round beam, off-axis, f/1.0, ~1cm flatness/path length
- Parts cost is trivial on LDRD scale $\$10^3 << \$10^5$, and much smaller than physicist's time cost
- Should be tilt- and steer-able to at least 20 degrees from zenith; need to integrate with interface to ground and horn receiver support
- What is the advantage of home-brew over buying from General Dynamics or eBay? (1) Gain experience, (2) Naturally extend design for larger instruments, D ~ 10m or 30m

Backup, further notes

Tilt, or whirl?





Building the prototype with a vertical beam is inefficient in terms of the truss, though it is simpler because the truss planes are all vertical; focus support tower can be on a disconnected footprint.

With a beam set at 20deg the dish is much closer to horizontal, the truss is smaller, and the focus is over the dish.

Fixed tilt beam can still scan the sky if the assembly rotates around the vertical.

Environmental factors

- On Long Island, need to worry about:
  - High winds (50 mph)
  - Salt air, high humidity
  - Snow loads (15-30 lb/ft^2)
  - Freezing rain and ice accumulation
  - Temperature swings (80 degF = $\Delta l/l \sim 10^{-3}$ for Al)

- Also keep in mind
  - Requirements for technicians and union labor in design, machining, and assembly at BNL